Tag			Function	Failure	Hazard/Effect	Hazard	Remarks/Recommendations
PI	1	PG	Outer vessel local pressure gage	Incorrect reading	Can use pressure transmitter information on CMORE panel.	none	
PSV	1	PG	Outer vessel main relief valve, 400 psig	Fails Open	The vessel will depressurize. Some glycol will be released. Bellows of bubble chamber may rupture.	MD	Detector downtime to fix is significant, 3-4 months? ASME valve is highly reliable. Diverter valve can isolate it for change out.
PSV	1	PG	Outer vessel main relief valve, 400 psig	Fails Closed	Weakest component (MV-84?) will rupture. Bellows of BC may rupture.	MD	ASME valve is highly reliable.
MV	2	PG	Spare instrumentation tree port valve	Fails Open	none	Safe	Valve outlet is capped.
MV	2	PG	Spare instrumentation tree port valve	Fails Closed	none	Safe	Used as an air bleed in, not critical.
PT	2	PG	Outer vessel pressure transmitter-Slow	Incorrect reading	Pump pressure control incorrect	Safe	Redundant. Fast pressurization still active. Comparison to PT3,PT5
MV	3	PG	Purge vent valve	Fails Open	None. Extra piping will be included in the pressure/expansion volume.	Safe	
MV	3	PG	Purge vent valve	Fails Closed	Difficulty during initial purge of air from system	Safe	Used only during initial start up and at very low pressure.
PT	3	PG	Outer vessel pressure transmitter-Fast	Incorrect reading	Fast pressurization trigger could be delayed causing larger bubble size.	Safe	Redundant. Comparison to PT3,PT5. Operational issue.
ZT	4		Bubble chamber bellows position	Incorrect reading	Not used for control. Will cause an alarm.	Safe	Position is manually indicated as well.
MV	5	PG	High point purge valve	Fails Open	None. Extra piping will be included in the pressure/expansion volume.	Safe	
MV	5	PG	High point purge valve	Fails Closed	Difficulty during initial purge of air from system	Safe	Used only during initial start up and at very low pressure.
PT	5	PG	Outer vessel pressure trans. Very Fast	Incorrect reading	Fast pressurization trigger could be delayed causing larger bubble size.	Safe	Redundant. Comparison to PT2,PT3. Operational issue.
PT	5	PG	Outer vessel pressure trans. Very Fast	has leak	Loss of glycol and could de-pressurize outer vessel. Could eventually lead to mechanical damage of BC.	Safe	Leak will be slow, easy to isolate and fix before it is an issue.
MV	6	PG	Recompression port isolation on lid	Fails Open	None. Normally open.	Safe	Used to isolate pressure vessel if recompression cylinder needs work.
MV	6	PG	Recompression port isolation on lid	Fails Closed while BC expanded	Fast recompression is not possible.	Safe	Bubble will grow larger than desired and stop at saturation pressure of 105 psia.
MV	6	PG	Recompression port isolation on lid	Fails Closed while BC pressurized	None. Pump will maintain pressurized state	Safe	De-pressurization cycle will not occur.
ZT	6		Recompression cylinder position	Incorrect reading	Pump will not dock piston to correct position when pressurized. Could overpressurize vessel.	Safe	Pump will be interlocked on high pressure. Vessel protected by reliefs.
MV	7	PG	Recirculation valve for de-gassing	Fails Open	Extra piping will be included in the pressure/expansion volume.	Safe	
MV	7	PG	Recirculation valve for de-gassing	Fails Closed	Normal. Difficulty during initial purge of air and de-gassing system	Safe	Used only during initial start up.
PIT	7	A	Air reservoir pressure transmitter	Reads high	Will cause an alarm but no action.	Safe	recompression air supply
PIT	7	A	Air reservoir pressure transmitter	Reads low	Will cause a fast recompression	Safe	This an interlock to guard against house air loss.
EV	8	A	Fast recompression air valve	Cylinder to vent	Unable to quickly re-compress. Pressure control hampered.	MD	Piston travel will go to end of stroke. Bubble will stop at saturation pressure of 105 psia.
EV	8	A	Fast recompression air valve	Cylinder to tank	Will not be able to de-pressurize.	Safe	Pressurized is the desired safe condition.
FI	8	PG	Pump flow indicator	Incorrect reading	None	none	
FI	8	PG	Pump flow indicator	has leak	Loss of glycol during pump emptying & filling operations.	Safe	Normally isolated. Emptying & filling are attended operations.
MV	9	A	De-pressurization rate metering valve	Fails Open	Depressurization rate will be quicker than desired.	Safe	Re-compression triggers still active.
MV	9	A	De-pressurization rate metering valve	Fails Closed	Will not be able to de-pressurize.	Safe	Pressurized is the desired safe condition.
WT	9	PG	Diaphragm tank weight	Incorrect reading	May fill tank too little or too much. Can trigger an alarm.	Safe	Alarm indication only. Filling is a controlled thing with measured amounts monitored.

Tag			Function	Failure	Hazard/Effect	Hazard	Remarks/Recommendations
PI	10	A	Diaphragm tank air pressure	Incorrect reading	Pump suction pressure will look suspect	none	Redundant with PT43. Should stay constant once charged.
PV	10	A	Pressure regulation	Fails full open	Air tank has operational relief at 70 psig, outer vessel will pressurize to 280 psig	Safe	The operational relief was added based on this FMEA analysis.
PV	10	A	Pressure regulation	Fails closed	Air tank pressure will be low limiting re-compression pressure	Safe	PIT7 will trigger a re-compression and hold at low air tank pressure.
LI	11	PG	Degassing chamber level	Reads high	Could empty tank. Might get gas into glycol system.	Safe	
LI	11	PG	Degassing chamber level	Reads low	Could overfill tank. Possible vacuum pump damage.	Safe	Unlikely. Measuring amount of fluid transferred.
PSV	11	PG	Outer vessel main relief valve, 400 psig	Fails Open	The vessel will depressurize. Some glycol will be released. Bellows of bubble chamber may rupture.	MD	Detector downtime to fix is significant, 3-4 months? ASME valve is highly reliable.
PSV	11	PG	Outer vessel main relief valve, 400 psig	Fails Closed	Weakest component (MV-84?) will rupture. Bellows of BC may rupture.	MD	ASME valve is highly reliable. Relief case is unlikely to occur.
MV	12	PG	Instrumentation isolation	Fails Open	Normally open. Makes instrumentation change-outs difficult.	Safe	
MV	12	PG	Instrumentation isolation	Fails Closed	Incorrect readings from pressure transmitters	Safe	PLC logic comparing expected pressure to actual pressure will latch a compressed state.
PI	12	V	Vacuum pump inlet pressure	Incorrect reading	none	Safe	
ZI	12		Bellows length indicator	Incorrect reading	Not possible, direct connection to bellows	Safe	
PT	13	V	Interspace pressure b/w two seals	Incorrect reading	Uncertainty of seal integrity.	Safe	Can evacuate thru MV-16 and use different gage.
SV	13	A	Air reservoir main safety relief	Fails Open	The vessel will depressurize. CF3I Bubble can grow. Recompression cylinder will bottom out and hold saturation pressure.	Safe	
SV	13	A	Air reservoir main safety relief	Fails Closed	Tank may not be protected in a fire condition.	Safe	Source pressure is a maximum of 120 psig. Operational relief at 70 psig would be open.
PSV	14	PG	Outer vessel operational relief valve, 300 psig	Fails Open	The vessel will depressurize. Some glycol will be released. Bellows of bubble chamber may rupture.	MD	Detector downtime to fix is significant, 3-4 months? Valve was tested prior to installation.
PSV	14	PG	Outer vessel operational relief valve, 300 psig	Fails Closed	Outer vessel & BC pressure will rise to PSV-1/11 setpoint = 400 psig. MV-84 exceeds 375 psig rating.	MD	ASME valve is highly reliable. Relief case is unlikely to occur.
SV	14	PG	Outer vessel main relief valve, 400 psig	Fails Open	The vessel will depressurize. Some glycol will be released. Bellows of bubble chamber may rupture.	MD	Detector downtime to fix is significant, 3-4 months? ASME valve is highly reliable. Diverter valve can isolate it for change out.
SV	14	PG	Outer vessel main relief valve, 400 psig	Fails Closed	Weakest component (MV-84?) will rupture. Bellows of BC may rupture.	MD	ASME valve is highly reliable.
MV	15	PG	Auxilliary port on outer vessel	Fails Open	Loss of glycol and could de-pressurize outer vessel. Could eventually lead to mechanical damage of BC.	MD	Will cap outlet to prevent accidental opening.
MV	15	PG	Auxilliary port on outer vessel	Fails Closed	None	MD	
MV	16	V	Double seal integrity/evacuation port	Fails Open	Small amount of air between seals	Safe	Both seals are leak checked at assembly.
MV	16	V	Double seal integrity/evacuation port	Fails Closed	None.	Safe	Normally closed and capped.
MV	17	PG	Outer vessel Relief valve selector	Fails to turn	Will not be able to isolate a leaking or malfunctioning relief valve.	MD	Unlikely double failure. Could result in bellows rupture.
MV	17	PG	Outer vessel Relief valve selector	Fails mid-swing	None, both relief valves will be on-line with sufficient flow area.	Safe	
MV	18	PG	SV-14 isolation	Fails Open	Unable to replace PSV-14 if it starts leaking	Safe	Can plug PSV-14 and rely on PSV-1 or PSV-11
MV	18	PG	SV-14 isolation	Fails Closed	Operational relief isolated. Large reliefs handle all relieving conditions. Large reliefs may not reseal well.	Safe	
MV	19	A	accumulator charging shrader valve	Fails Open	Accumulator loses bladder pressure. Pressure spike at fast recompression will be close to 275 psig.	Safe	Peak spikes are below relief valve settings.
MV	19	A	accumulator charging shrader valve	Fails Closed	Unable to charge accumulator	Safe	Can be replaced easily enough.
MV	20	A	Air port on diaphragm tank	Fails Open	Pump suction goes to atmospheric pressure. Pumping hampered.	Safe	
MV	20	A	Air port on diaphragm tank	Fails Closed	None	Safe	Only used during initial start up to set pump suction pressure.
LI	21	W	Water tank level indicator	False indication	Could overfill or underfill water tank.	Safe	This is redundant with level transmitter.

Tag			Function	Failure	Hazard/Effect	Hazard	Remarks/Recommendations
SV	21	A	Diaphragm tank main relief	Fails Open	Pump suction goes to atmospheric pressure. Pumping hampered.	Safe	
SV	21	A	Diaphragm tank main relief	Fails Closed	Vessel is not protected during fire case.	Safe	ASME valve is highly reliable. Relief case is unlikely to occur. Recompression cylinder glycol volume not capable of overpressurizing due to bladder volume.
MV	22	PG	Diaphragm tank isolation valve	Fails Open	None. Normally open.	Safe	
MV	22	PG	Diaphragm tank isolation valve	Fails Closed	Outer vessel pressure control will be one directional, downward. PSV-35 may relieve glycol on floor if pump runs to bring down vessel pressure.	Safe	Worst case, outer vessel pressure will stop at CF3I saturation pressure, 90 psig.
LT	22	W	Water tank level sensor	Incorrect reading	Too high or low water level. Redundant with LI-21.	Safe	Water level can vary +/-5" without worry.
MV	23	PG	Diaphragm tank isolation valve	Fails Open	None. Normally open.	Safe	
MV	23	PG	Diaphragm tank isolation valve	Fails Closed	Outer vessel pressure control will be one directional, downward. PSV-35 may relieve glycol on floor if pump runs to bring down vessel pressure.	Safe	Worst case, outer vessel pressure will stop at CF3I saturation pressure, 90 psig.
MV	24	PG	Pump suction isolation valve	Fails Open	None. Normally open.	Safe	
MV	24	PG	Pump suction isolation valve	Fails Closed	Outer vessel pressure control will be one directional, downward. PSV-35 may relieve glycol on floor if pump runs to bring down vessel pressure.	Safe	Worst case, outer vessel pressure will stop at CF3I saturation pressure, 90 psig.
MV	25	PG	Pump discharge to vessel isolation	Fails Open	None. Normally open.	Safe	
MV	25	PG	Pump discharge to vessel isolation	Fails Closed	Loss of slow pressure control of outer vessel by pump.	Safe	Worst case, outer vessel pressure will stop at CF3I saturation pressure, 90 psig.
MV	26	PG	De-gassing tank liquid side	Fails Open	None. Extra piping will be included in the pressure/expansion volume. Other valves are closed.	Safe	Used during initial fill by sucking fluid with vacuum pump.
MV	26	PG	De-gassing tank liquid side	Fails Closed	Need to use pump to pump fluid to fill vessel/system.	Safe	
MV	27	PG	Fluid fill line for fast cylinder	Fails Open	Normally open.	Safe	
MV	27	PG	Fluid fill line for fast cylinder	Fails Closed	Will lose fine pressure control.	Safe	Used to compensate for temperature changes in fluid and or minor leaks.
MV	28	PG	Vessel bottom entry port	Fails Open	None.	Safe	Parallel path to top entry.
MV	28	PG	Vessel bottom entry port	Fails Closed	Will hamper normal bottoms up fill operations	Safe	Parallel path to top entry.
MV	29	PG	Vessel bottom drain port	Fails Open	None. Outlet is capped.	Safe	Used to drain vessel.
MV	29	PG	Vessel bottom drain port	Fails Closed	None.	Safe	Can use MV-28 to drain.
MV	30	PG	Pump bypass or diaphragm fill	Fails Open	None. Other valves down stream are closed	Safe	
MV	30	PG	Pump bypass or diaphragm fill	Fails Closed	None. Normally closed.		Initial pump fill of diaphragm tank difficult will require different valve line-up.
TE	30	PG	Glycol fluid temperature	Incorrect reading	Incorrect operating point for data analysis	Safe	Redundant with other sensors
TT	30	PG	Glycol fluid temperature	Incorrect reading	Incorrect operating point for data analysis	Safe	Redundant with other sensors
MV	31	PG	2" hose gas bleed off	Fails Open	None. Extra piping will be included in the pressure/expansion volume. Other valves are closed.	Safe	
MV	31	PG	2" hose gas bleed off	Fails Closed	Can't get gas pocket out of large hose high point.	Safe	Extra gas make pressure control response spongy.
TE	31	PG	Glycol fluid temperature	Incorrect reading	Incorrect operating point for data analysis	Safe	Redundant with other sensors
TT	31	PG	Glycol fluid temperature	Incorrect reading	Incorrect operating point for data analysis	Safe	Redundant with other sensors
MV	32	PG	Pump bypass	Fails Open	None. Other valves down stream are closed	Safe	
MV	32	PG	Pump bypass	Fails Closed	Normally closed. Will prevent pump driven emptying of outer vessel.	Safe	Can use pressurized draining procedure.
MV	33	PG	high point gas bleed below MV-6	Fails Open	None. Extra piping will be included in the pressure/expansion volume.	Safe	
MV	33	PG	high point gas bleed below MV-7	Fails Closed	Difficulty during initial purge of air from system	Safe	Used only during initial start up and at very low pressure.
TE	32	PG	Glycol fluid temperature	Incorrect reading	Incorrect operating point for data analysis	Safe	Redundant with other sensors
TT	32	PG	Glycol fluid temperature	Incorrect reading	Incorrect operating point for data analysis	Safe	Redundant with other sensors
TE	33	PG	Glycol fluid temperature	Incorrect reading	Incorrect operating point for data analysis	Safe	Redundant with other sensors
TT	33	PG	Glycol fluid temperature	Incorrect reading	Incorrect operating point for data analysis	Safe	Redundant with other sensors

Tag			Function	Failure	Hazard/Effect	Hazard	Remarks/Recommendations
SV	34	PG	Pump discharge relief valve	Fails Open	Loss of glycol and could de-pressurize outer vessel. Could eventually lead to mechanical damage of BC.	MD	High setpoint, unlikely to ever relieve or open/fail open except when isolated from outer vessel.
SV	34	PG	Pump discharge relief valve	Fails Closed	PT-41 damage if pump is deadheaded.	MD	Relief SP = 500 psig, PT proof pressure=750 psig
TE	34	W	Chiller/heater return temperature	Incorrect reading	Incorrect operating point for data analysis	Safe	Redundant with other sensors
SV	35	PG	Pump suction relief valve	Fails Open	Loss of glycol and could de-pressurize outer vessel. Could eventually lead to mechanical damage of BC.	MD	Unlikely to relieve. Can be isolated from outer vessel if leaking.
SV	35	PG	Pump suction relief valve	Fails Closed	Pump damage if pump dead headed when running in reverse.	MD	Pump would likely fail by seal leakage rather than catastrophically.
TE	35	W	Chiller/heater supply temperature	Incorrect reading	Incorrect operating point for data analysis	Safe	Redundant with other sensors
MV	36	PG	Outer vessel bottom fill	Fails Open	None.	Safe	Parallel path to top entry.
MV	36	PG	Outer vessel bottom fill	Fails Closed	Will hamper normal bottoms up fill operations	Safe	Parallel path to top entry.
MV	37	PG	Pump suction return from de-gas tank	Fails Open	None	Safe	Other valves downstream can be closed.
MV	37	PG	Pump suction return from de-gas tank	Fails Closed	Hinders pump filling or draining operations.	Safe	
MV	38	PG	Pump suction return from vessel	Fails Open	None	Safe	Other valves downstream can be closed.
MV	38	PG	Pump suction return from vessel	Fails Closed	Hinders pump filling or draining of diaphragm tank.		
MV	39	PG	Pump to de-gassing tank	Fails Open	None	Safe	Other valves downstream can be closed.
MV	39	PG	Pump to de-gassing tank	Fails Closed	Hinders pump filling or draining operations.	Safe	
MV	40	PG	Particulate filter isolation	Fails Open	None. Filter change not possible with de-gas tank full.	Safe	
MV	40	PG	Particulate filter isolation	Fails Closed	Hinders glycol filling operations.	Safe	
MV	41	PG	Glycol fill port isolation	Fails Open	Possible glycol spill. Hinders filling system with glycol.	Safe	Secondary containment will be in place.
MV	41	PG	Glycol fill port isolation	Fails Closed	Hinders filling system with glycol.	Safe	
PT	41	PG	Hydraulic pump discharge pressure	Incorrect reading	Could relieve glycol at PSV-34	Safe	Fluid rate slow. Redundant information if open to the outer vessel. Not used for automatic control.
MV	42	PG	Sight level gage fluid side	Fails Open	Normal. Can't isolate sight glass if it needs repair.	Safe	
MV	42	PG	Sight level gage fluid side	Fails Closed	Erroneous level indication in de-gassing tank.	Safe	Possible to overfill tank, but operator would notice no level change during filling and stop the fill until fixed.
MV	43	PG	Sight level gage gas side	Fails Open	Normal. Can't isolate sight glass if it needs repair.	Safe	
MV	43	PG	Sight level gage gas side	Fails Closed	Erroneous level indication in de-gassing tank.	Safe	Possible to overfill tank, but operator would notice no level change during filling and stop the fill until fixed.
PT	43	PG	Hydraulic pump discharge pressure	Incorrect reading	Could relieve glycol at PSV-35	Safe	Fluid rate slow. Not used for automatic control.
MV	44	V	De-gassing tank to vacuum pump	Fails Open	Cannot suck fluid from de-gassing tank thru outer vessel.	Safe	Can use a pump fill operation
MV	44	V	De-gassing tank to vacuum pump	Fails Closed	Cannot de-gas fluid.	Safe	Operational issue.
PI	44	PG	Degassing chamber pressure	Incorrect reading	Will not know pressure of degassing tank	none	Can infer from other gages when operating.
MV	45	N	Air bleed in port for de-gas tank	Fails Open	Can't de-gas fluid.	Safe	Can cap end of pipe.
MV	45	N	Air bleed in port for de-gas tank	Fails Closed	Filling or draining operations impaired.	Safe	
PI	45	PG	Degassing chamber vent line	Incorrect reading	None, can change out gage	none	
SV	46	PG	Degassing tank main relief	Fails Open	Can't de-gas fluid.	Safe	Can change it.
SV	46	PG	Degassing tank main relief	Fails Closed	Tank not directly protected from pressurization.	Safe	Relief valves are reliable. Multiple valves need to be lined up in a certain configuration for pressurizing.
EV	47	PG	Pump discharge isolation	Fails Open	Operational inconvenience	Safe	Redundant with MV-25.
EV	47	PG	Pump discharge isolation	Fails Closed	Loss of slow pressure control of outer vessel by pump.	Safe	Worst case, outer vessel pressure will stop at CF3I saturation pressure, 90 psig.
MV	48	PG	De-gassing tank gas line	Fails Open	Can't isolate de-gassing skid for disconnection & tranport.	Safe	Redundant with MV-72
MV	48	PG	De-gassing tank gas line	Fails Closed	Cannot fill or de-gas outer vessel.	Safe	Typically only used at startup.
MV	49	PG	Particulate filter isolation	Fails Open	None. Filter change not possible with de-gas tank full.	Safe	
MV	49	PG	Particulate filter isolation	Fails Closed	Hinders glycol filling operations.	Safe	
CV	50	V	Vacuum pump	Sticks open	None	Safe	
CV	50	V	Vacuum pump	Sticks closed	Evacuating or suck filling outer vessel hampered.	Safe	Can go through a parallel path.
FI	50	W	Chiller return flow	Incorrect reading	None	Safe	Indication only.

Tag			Function	Failure	Hazard/Effect	Hazard	Remarks/Recommendations
PSV	51	PG	Flow indicator protection	Fails Open	Operational nuisance. Will need to replace.	Safe	
PSV	51	PG	Flow indicator protection	Fails Closed	Possible to overpressurize FI-55.	Safe	Normal pressures are well below FI-55 rating.
RO	52	PG	Restricting orifice union, 0.8" dia.	Clogs	Pressurization of BC will be slow.	Safe	Can pressurize through bottom if necessary.
PI	54	A	Accumulator charge pressure	Incorrect reading	Buffer pressure will be too high or too low.	Safe	Pressure response curve will not be optimal.
FI	55	PG	Sight glass de-gassing tank top fill	Clogs or sticks	Indication only. Isolatable for repairs	Safe	
MV	55	PG	high point vapor bleed	Fails Open	Glycol leak. Can cap outlet of valve	Safe	Only used during initial de-gassing. Should cap after de-gassing is done.
MV	55	PG	high point vapor bleed	Fails Closed	Will need to lift relief valve seat to bleed.	Safe	We used to do this in the past before installing MV-55.
MV	56	PG	high point vapor bleed	Fails Open	Glycol leak. Can cap outlet of valve	Safe	Only used during initial de-gassing. Should cap after de-gassing is done.
MV	56	PG	high point vapor bleed	Fails Closed	Will need to lift relief valve seat to bleed.	Safe	We used to do this in the past before installing MV-55.
PSV	57	PG	Liquid line filter protection	Fails Open	Glycol leak. Can isolate and replace	Safe	
PSV	57	PG	Liquid line filter protection	Fails Closed	Possible to overpressurize filter housing if MV-40 is closed during pump transfer into de-gas tank.	MD	Failure will be non-catastrophic since it is fluid and not gas.
F	58	PG	Filter, de-gas tank liquid line	Clogs, bypasses	None	Safe	
PSV	60	A	Air Reservoir relief valve	Fails Open	Loss of air to do fast recompression.	Safe	PIT7 will trigger a re-compression and hold at low air tank pressure.
PSV	60	A	Air Reservoir relief valve	Fails Closed	Air pressure regulator can be set high enough to exceed outer vessel relief set points.	Safe	Outer vessel reliefs are sized with enough capacity.
MV	61	A	Air reservoir drain valve	Fails Open	Loss of air to do fast recompression.	Safe	PIT7 will trigger a re-compression and hold at low air tank pressure.
MV	61	A	Air reservoir drain valve	Fails Closed	Cannot drain accumulated water from air tank	Safe	Operational issue.
PV	62	A	diaphragm tank charging	Set too high	None.	Safe	
PV	62	A	diaphragm tank charging	Set too low	Hydraulic pump may not work. Loss of slow pressure control.	Safe	Fast pressure control will still work.
MV	70	W	Chiller/heater supply line	Fails Open	None	Safe	normally open
MV	70	W	Chiller/heater supply line	Fails Closed	Loss of heating or cooling of outer vessel glycol volume.	Safe	Operational issue.
MV	71	W	Chiller/heater return line	Fails Open	None	Safe	normally open
MV	71	W	Chiller/heater return line	Fails Closed	Loss of heating or cooling of outer vessel glycol volume.	Safe	Operational issue.
MV	72	PG	De-gassing tank gas line	Fails Open	Cannot fill outer vessel by sucking with vacuum pump.	Safe	Operational issue.
MV	72	PG	De-gassing tank gas line	Fails Closed	Can't pump out, suck fill or de-gas outer vessel volume.	Safe	Operational issue.
CV	73	Air	House air supply check valve	Sticks open	Will only have single isolation of air tank in the event of house air failure.	Safe	Double failure, PV10 needs to leak backward as well.
CV	73	Air	House air supply check valve	Sticks closed	Loss of house air will cause low air reservoir pressure.	Safe	Fast re-compression will trigger on low/dropping air reservoir pressure. Pump maintains pressure and piston position.
MV	75	PG	Block valve near de-gassing tank	Fails Open	Compromised de-gassing operation.	Safe	Ran without this valve at PAB.
MV	75	PG	Block valve near de-gassing tank	Fails Closed	None. Other flow path exists.	Safe	
MV	76	PG	Block valve near de-gassing tank	Fails Open	Compromised de-gassing operation.	Safe	Ran without this valve at PAB.
MV	76	PG	Block valve near de-gassing tank	Fails Closed	None. Other flow path exists.	Safe	
MV	77	PG	Bottom liquid drain at sight glass	Fails Open	Vacuum pump pressure will not be good.	Safe	
MV	77	PG	Bottom liquid drain at sight glass	Fails Closed	None. Inconvenience.	Safe	
PSV	78	PG	Sight glass over-pressure protection	Fails Open	Vacuum pump pressure will not be good.		
PSV	78	PG	Sight glass over-pressure protection	Fails Closed	Glass sight glass is vulnerable to higher pressures if operator makes error.	Safe	Excess pressure should escape through vacuum pump.
MV	79	PG	Block valve near de-gassing tank	Fails Open	None. Inconvenience.	Safe	
MV	79	PG	Block valve near de-gassing tank	Fails Closed	None. Inconvenience.	Safe	
MV	80	CF3I	PT83 Isolation	Fails Open	Possible contamination if PT-83 is removed.	Safe	
MV	80	CF3I	PT83 Isolation	Fails Closed	Incorrect or no reading on PT-83. PT-83 is redundant and is not used for control.	Safe	

Tag			Function	Failure	Hazard/Effect	Hazard	Remarks/Recommendations
MV	83	CF3I	Bubble chamber aux. port	Fails Open	Loss of Water then CF3I. Bellows of expansion chamber will collapse.	MD	Detector downtime to fix is significant, 3-4 months? We will cap outlet.
MV	83	CF3I	Bubble chamber aux. port	Fails Closed	None	Safe	
PT	83	CF3I	Bubble chamber pressure	Incorrect reading	Won't know differential pressure BC to outer vessel or absolute BC fluid pressure	Safe	Used for informational purposes and data analysis
MV	84	CF3I	Main Bubble chamber 1" fill port.	Fails Open	Loss of Water then CF3I. Bellows of expansion chamber will collapse.	MD	Detector downtime to fix is significant, 3-4 months? We will cap outlet.
MV	84	CF3I	Main Bubble chamber 1" fill port.	Fails Closed	None	Safe	Initial fill of bubble chamber is not possible.
TE	84		Outer vessel external wall temperature	Incorrect reading		Safe	Redundant with TE86, also will be correlated with inside glycol temps.
TS	85		Outer vessel heater interlock	Contacts open	Will shut off the vessel heater. Vessel will cool.	Safe	Set to open at 70 C
TS	85		Outer vessel heater interlock	Contacts closed	Will fail to shut off heater if temperature controller fails full on or heater fails full on.	Safe	Double failure. Heater pads are only 300 watts, steady state will not be extreme.
TE	86		Outer vessel external wall temperature	Incorrect reading		Safe	Redundant with TE86, also will be correlated with inside glycol temps.
TS	87		Outer vessel heater interlock	Contacts open	Will shut off the vessel heater. Vessel will cool.	Safe	Set to open at 70 C
TS	87		Outer vessel heater interlock	Contacts closed	Will fail to shut off heater if temperature controller fails full on or heater fails full on.	Safe	Double failure. Heater pads are only 300 watts, steady state will not be extreme.
			Outer vessel local pressure gage	has leak	Loss of glycol and could de-pressurize outer vessel. Could eventually lead to mechanical damage of BC.	Safe	Leak will be slow, easy to isolate and fix before it is an issue.
			Outer vessel pressure transmitter-Slow	has leak	Loss of glycol and could de-pressurize outer vessel. Could eventually lead to mechanical damage of BC.	Safe	Leak will be slow, easy to isolate and fix before it is an issue.
			Outer vessel pressure transmitter-Fast	has leak	Loss of glycol and could de-pressurize outer vessel. Could eventually lead to mechanical damage of BC.	Safe	Leak will be slow, easy to isolate and fix before it is an issue.
PI	90	W	Water system pressure	Incorrect reading	May not know filters are clogged.	Safe	
MV	90	W	PI-90 manifold block valve	Fails Open	None. Redundant with MV-97.	Safe	
MV	90	W	PI-90 manifold block valve	Fails Closed	Will lose pressure indication upstream of filters.	Safe	
MV	91	W	Water recirculation, pump suction	Fails Open	None. Normally open. Possilbe water spill during maintenance activities.	Safe	
MV	91	W	Water recirculation, pump suction	Fails Closed	Will stop water circulation. Loss of water temperature control.	Safe	Heater shuts off if flow switch indicates no flow.
MV	92	W	Water recirculation, pump discharge	Fails Open	None. Normally open. Possilbe water spill during maintenance activities.	Safe	
MV	92	W	Water recirculation, pump discharge	Fails Closed	Will stop water circulation. Loss of water temperature control.	Safe	Heater shuts off if flow switch indicates no flow.
MV	93	W	Water recirculation, fill/drain	Fails Open	Water leakage.	Safe	Used only during start up and draining.
MV	93	W	Water recirculation, fill/drain	Fails Closed	Cannot fill or drain water tank as intended.	Safe	Can use alternate means.
MV	94	W	Water system high point purge	Fails Open	Pump suction will lose it's prime.	Safe	
MV	94	W	Water system high point purge	Fails Closed	Normal.	Safe	
MV	95	W	Water filter housing high point purge	Fails Open	Water leakage.	Safe	
MV	95	W	Water filter housing high point purge	Fails Closed	None. Some air will be in filter, but okay.	Safe	
MV	96	W	Water filter housing tap	Fails Open	Water leakage.	Safe	
MV	96	W	Water filter housing tap	Fails Closed	None.	Safe	
MV	97	W	PI-90 manifold block valve	Fails Open	None. Redundant with MV-90.	Safe	
MV	97	W	PI-90 manifold block valve	Fails Closed	Will lose pressure indication upstream of filters.	Safe	
MV	98	W	PI-90 manifold block valve	Fails Open	May bypass water around filter.	Safe	
MV	98	W	PI-90 manifold block valve	Fails Closed	Unable to measure pressure after water filters.	Safe	Can measure pressure elsewhere.
MV	99	W	LI-21 purge valve	Fails Open	Loss of water level indication.	Safe	Redundant with level transmitter LT-22
MV	99	W	LI-21 purge valve	Fails Closed	Not able to purge water out of sensing line. Incorrect level indication.	Safe	Redundant with level transmitter LT-22